
The Foss Hybrid Tug: The Journey to the Future

Susan Hayman, (speaker/co-author), **Elizabeth Reynolds Boyd**, (speaker/co-author)
Foss, USA

SYNOPSIS

This paper presents a chronology of the design and construction of the world's first hybrid harbour tug as well as the impetus behind the concept. The paper focuses on the real world experience of operating the tug as a part of the Southern California fleet providing Green Assists™ to customers in San Pedro Harbour.

The perspective of the crewmembers and the nuances of operating this tug are discussed as well as the response from various stakeholders and customers. The engineering challenges associated with the construction and commissioning of this tug are also addressed as is the status and results of emissions testing and cost savings experience to date.

INTRODUCTION

Rather than focus on the merits of the hybrid technology used to develop Foss's hybrid tug, which are well documented in previously submitted documents and presentations and widely understood, the theme of this paper is Foss's real operating experience with the hybrid tug. This tug, **Carolyn Dorothy**, operates as a part of the Foss Southern California fleet providing Green Assists™ to customers in San Pedro harbour and has been in service for just over one year. Foss has been very pleased with the performance of the tug, and in several important areas **Carolyn Dorothy** has exceeded our expectations.

The impetus for building the hybrid tug was to reduce our emissions footprint. We have succeeded in our overarching goal and are pleased to discuss the recently conducted independent emissions testing on the vessel, along with the methodology and testing protocols used. Designing, building and operating the world's first hybrid tug was not without its challenges. However, we do feel **Carolyn Dorothy** represents an effective solution to the environmental problems facing our industry.

Foss believes the hybrid option is the best solution to lower emissions and optimise efficiency for harbour tugboats due to their highly variable duty cycle. The Foss/AKA hybrid system is composed of electric and mechanical power sources with batteries playing a vital role in energy storage.

Carolyn Dorothy is a Robert Allan Ltd designed Dolphin class tug 23.8m in length, 10.4m wide with 5,080hp and over 54.4 tonnes of bollard pull. From the

outside this tug looks like its nine sister Dolphin tugs, but the engine room has smaller main engines and the hybrid package.

The vessel operates in three primary modes while in use. When stopped, batteries are recharged through a shorepower connection. In the first mode, idle, the boat hotels from the batteries and can transit at about 3 knots. One of the generators comes on line to recharge the batteries once they are discharged below the 30 per cent level. When the boat is in the second mode, transit, one or both generators are on line depending on the desired speed. The vessel achieves a speed of up to 6.5 knots with just one generator and approximately 8 knots with both generators, if a faster transit is required. While transiting, the generators are also concurrently providing the hotel services and recharging the batteries when needed. While in the third mode, assist, both main engines and both generators come on line providing 58 tonnes of bollard pull.

BACKGROUND AND CHRONOLOGY

The concept of using hybrid technology for tugboats had long been considered by Foss. John Barrett, Foss's director of Fleet Engineering, had been following the progress of hybrid technology for several years because of the indisputable logic that optimising power sources is the future for harbour tug designs.

In 2006, Foss began a more aggressive programme to develop or deploy technologies to reduce emissions from our boats. By this point hybrid systems had progressed to switcher locomotives so it was felt that the time was right to revisit the idea of a hybrid tugboat. A small team was put together to research and explore possible design

solutions. When the team was satisfied that the concept could become a reality and a preliminary design was conceived, it searched for a partner who shared its vision and who could bring the technical expertise to design and build the energy management system.

In the fall of 2006, Foss was fortunate to find a partner in Aspin Kemp and Associates (AKA) who understood the need for redundancy and fail-safe operations. The first half of 2007 was spent finalising the initial design with team members from Foss, AKA and Robert Allan Ltd. Construction of the vessel began in September 2007 at the Foss shipyard in Rainier, Oregon.



However, five months into construction the battery manufacturer withdrew from the market and ceased production of the nickel metal hydride battery we had selected. We waited until we could find a suitable replacement for the discontinued battery, and resumed construction in April 2008.



On 17th January 2009, **Carolyn Dorothy** arrived in Long Beach. During the months of January and February, the boat was transitioning into service while completing final commissioning work. We consider that **Carolyn Dorothy** officially entered full-time service providing Green Assists™ in San Pedro harbour on 1st March, 2009, just over one year ago.

Commissioning the system presented many challenges. In a normal commissioning operation each piece of machinery is tested against manufacturers' standards

and Foss runs its own set of standard tests, including, of course, a bollard test. However, with the new hybrid system it was necessary to ensure that not only did each individual piece of equipment function properly throughout its full operating range, but also that each part of the system came on and off line smoothly for numerous changes in required operating power. It was necessary to ensure that the system would respond to the operators through any sequence of manoeuvres and a large matrix of tests was designed to cover the operating range.

Finally, an exhaustive failure mode analysis-testing programme was implemented. The boat was put through simulated normal and extreme working scenarios and subjected to controlled 'failure' of individual hybrid components to confirm that the system would respond to each simulated failure in the safest way possible.



The bollard pull tests were highly successful, with the boat pulling 58 tonnes. Following this test, an adjustment was made to the operating system to let the captain push a button for battery boost in high power situations. In all except perhaps an emergency situation, the incremental power attributable to the batteries is not needed. Originally, the system was designed to always use the batteries at the top end, but with the high bollard numbers achieved without batteries, we made this change to allow batteries to be used only when needed in order to extend battery life, while still having the extra power available when needed.

WELCOME TO SOUTHERN CALIFORNIA

The Southern California air district and the ports of Los Angeles and Long Beach provided funding assistance to offset the increased capital costs of the hybrid tug. Port officials were very pleased that Foss was able to completely fulfil its commitments and deliver the world's first hybrid tug to Southern California. Foss hosted a well-attended unveiling party in Long Beach on 23rd January, 2009.



Both the Ports and regulatory bodies in California have praised Foss for the low emissions hybrid tug. For example, Geraldine Knatz, executive director for the Port of Los Angeles said: “Foss’s corporate colour is green, which is symbolic because I believe it represents this organization’s thinking from top to bottom on the environment. Their innovative hybrid tug concept is a shining example of a company that has created a vision for greening their area of port operations”.

In a similar vein, Richard Steinke, executive director of the Port of Long Beach, said: “Foss is committed to reducing its carbon and emissions footprints and has undertaken major corporate initiatives to improve the air quality in Southern California.”

Foss has also received overwhelmingly positive comments from customers including Lance Laffoon, director of NYKCool who said: “We applaud Foss Maritime for the development and creation of Green Assist™ Hybrid tug. The commitment of Foss Maritime to work their environmental values into their business strategies is truly commendable. The development and creation of Green Assist™ Hybrid tug is a banner representation of Foss Maritime’s very commendable commitment to work environmental values into their business strategies.”

Of course the toughest crowd to please is arguably our boat crews who live and work on this boat on a daily basis. The pride, hard work and positive attitude of our Southern California team made a huge contribution to the success of this vessel during its first year of operation.

Our Southern California office has also been very accommodating for the many requests for tours and media coverage especially during the first six months of operation. This has not always been easy given the fact the Los Angeles/Long Beach port complex is one of the busiest in the world and all of our tugs do multiple jobs every day.

The pilots are also important stakeholders, requestors of service and direct users in port operations and gaining their confidence was a key factor in gaining acceptance of a hybrid tugboat in the harbour. John Strong, VP of Jacobsen Pilot Service has said: “As pilots, the nice thing about the **Carolyn Dorothy** being a hybrid tug is that the power and manoeuvrability is the same as the non-hybrid Dolphin class tugs and it also makes a positive difference for air quality.”

The Dolphin class tug design has been a huge success in the Los Angeles/Long Beach harbours, being widely accepted by customers, pilots and our crews as a state-of-the-art platform for ship assist work. Our tugs in this port not only do ship assist and tanker escort work but they also move barges in the harbour. Foss has three new double-hulled petroleum barges with vapour recovery systems in Southern California where a substantial amount of vessel bunkering is carried out. During nine months of

operation in 2009, the hybrid tug completed 826 ship assists and 320 barge moves.

THE OPERATOR’S PERSPECTIVE



The operator’s perspective can be taken from both above and below deck. One of the challenges from the maintenance perspective is that the troubleshooting was more difficult because of the greater complexity of the system.

After the commissioning, a ‘black box’ system was implemented that records all inputs and outputs of the system. The data can be reviewed remotely and this tool has greatly improved the ability to quickly identify and solve any problems.

Our captains have been unanimous in their assessment that **Carolyn Dorothy** even handles better than the sister Dolphin boats. The tug sits about 150mm deeper in the water and has a lightship displacement of 297 tonnes. This is approximately 30 tonnes more than its sister Dolphin tugs. Those who operate the tug comment that the design and operating procedures are intuitive and seamless.

The crew members appreciate the quiet operation of the tug when running off the batteries. When transiting, the vessel is also quieter because of the smaller size of the auxiliaries when compared with the main engines. Of course there is also a certain pride factor associated with operating such a unique vessel.

EMISSIONS TESTING

The motivation for Foss to build this tug was to reduce emissions. Starcrest Consulting had done some preliminary calculations of emissions reductions based on the engine types and duty cycle expectations but more extensive emissions testing was planned for after the tug entered service.

One of the things learned through this project is that emissions’ testing is much more complicated and difficult than any of us imagined. We were fortunate that experts at the California Air Resources Board (CARB) managed this endeavour. CARB has a contract with the University

of California at Riverside (UCR) under the auspices of the College of Engineering Center for Environmental Research and Technology (CE-CERT) programme to complete emissions testing for projects such as this.

Foss, along with Starcrest Consulting, worked with CARB and UCR to develop a test plan which was completed in September 2009. The next task was to form a Technical Working Group (TWG) composed of all the stakeholders involved with the project and other subject matter experts. Members of the TWG include EPA, CARB, the Pacific Merchant Shipping Association, the Ports of LA and Long Beach, Starcrest Consulting, Foss and UCR.

The test plan was reviewed and approved by the TWG in January 2010. The test plan is very detailed but the basic concept is that **Carolyn Dorothy** was compared against the sister conventional Dolphin boat, **Alta June**. Both boats are home ported in Long Beach and have similar operating profiles in San Pedro harbour. The emissions of these vessels were compared at seven different modes of operation.

The first phase of the testing was data logging. In January of this year a data logger and event logger were installed in **Alta June**. Data and operating information was continually downloaded from the main and auxiliary engines of the vessel and transmitted to the CE-CERT lab at UCR for 30 days. Concurrently the vessel captain used an event logger on the bridge to record when changing between the different defined modes. This event log data was then combined with GPS and log book information to develop the operating profile to merge with the data logger downloads.

In addition to the data logging exercise, in-use emissions testing was also completed on the main and auxiliary engines of **Alta June** in January even though these engines are all EPA-certified Tier 2 engines.

Once testing was completed on **Alta June**, the same data logging and emissions testing were transferred to **Carolyn Dorothy** in mid-February. Data logging and event logging was conducted on this vessel for another 30 days.



FUEL SAVINGS

In the design stage, it was estimated that the hybrid system would save 20-30 per cent in fuel over one of our conventional Dolphin boats operating in the same service. Early in the commissioning process there were hints that the performance in this respect would meet

these expectations. During trials the boat ran at 3 knots on batteries alone and at 8 knots on the two generators alone. Both of these speeds were better than expected and we were able to adjust settings of the power management system to further optimise performance and fuel efficiency.

Operating logs and fuel logs show that our actual fuel savings are in the upper end of the predicted range. We are currently using our black box system to record more detailed data for a full analysis, and we are also measuring fuel burn during our emissions testing programme. These steps will help refine the numbers further.

MAINTENANCE SAVINGS

One of the significant savings of the system, and one that is perhaps most overlooked by those who do not manage operations and maintenance of vessels, is the reduction of maintenance costs due to lower main engine hours.

A highly utilised harbour tug will operate 5,000-6,000 hours per year. In a conventional tug, both main engines are running every one of those hours. The hybrid system cuts down those main engine hours by 60 per cent or more. In engines where maintenance intervals are dictated by engine hours, this means that the time between overhauls is extended.

In addition, the hybrid system runs all engines at higher loads, closer to their optimal operating range. This avoids the problem in harbour service of many hours at idle, which can contribute to additional maintenance costs.

CONCLUSIONS

We feel this low emissions hybrid tug has been a great success. The Hybrid is the new generation of Dolphin. While the technology is not limited to our Dolphin class tugs, we will work to incorporate improvements based on the knowledge Foss and our partners AKA have gained through the commissioning and operation of **Carolyn Dorothy**. The next logical step in the hybrid programme is to retrofit existing tugs to incorporate the hybrid system.

This project has been an exciting, challenging and rewarding journey for all of us associated with this tug. We believe it is a real technological advance for our industry in finding effective, practical solutions to reduce the emissions inherent in our operations.

